Fact Sheet on Power Plant Emissions of Mercury in Virginia
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By Rodney Sobin, Office of Air Permit Programs, Virginia DEQ

Summary[1]

- Mercury (Hg) is a neurotoxin that can cause brain development defects in fetuses and impede intellectual development in children.
- Studies estimate that one to eight percent of American women of childbearing age may have Hg at levels of concern.
- Hg levels in certain species of both freshwater and marine fish have prompted federal and state advisories and cautions on fish consumption. A number of Virginia waterways are subject to these advisories.
- While some waterways are most affected by specific industrial or contaminated site mercury sources or by effluents from municipal wastewater treatment, many sites appear to be most affected by air deposition. Slow flowing, acidic "blackwaters" such as in Southeastern Virginia appear to be most vulnerable due to conditions that favor formation of methylmercury, a toxic form that biomagnifies in the food chain.
- A Florida Everglades study shows a strong correlation between reduction in local Hg emissions and reductions of Hg levels in fish and wildlife. A less strong correlation is found in Eastern North Carolina. Both local/in-state and longer distance transport are likely to affect Hg deposition in Virginia.
- Coal-fired electrical generating units (EGUs) are the largest manmade source of Hg emissions, accounting for 40% nationally. Virginia EGUs emit roughly 0.6 to 0.7 tons per year.
- Particulate matter (PM) and sulfur dioxide (SO_2) controls yield Hg control as a co-benefit. Plants that employ flue-gas desulfurization (FGD) plus fabric filter can control over 80% and even over 90% of Hg emissions from bituminous coal burning. FGD plus cold-side electrostatic precipitator (CS-ESP) may remove over half of Hg. CS-ESP alone may remove a quarter to a half of Hg. Hot-side ESPs (HS-ESP) are much less effective. Selective catalytic reduction (SCR) of NOx can enhance Hg removal.
- Virginia EGUs employing FGD plus fabric filter are estimated to remove over 90% of Hg. Plants using only CS-ESP are estimated as removing 29% while plants using only HS-ESP remove only 11%.
- Activated carbon injection has been shown at commercial scale to achieve over 70% Hg removal by PM controls in the absence of FGD. Use of fabric filter increases capital cost but reduces activated carbon costs relative to ESP. Incomplete combustion to leave carbon in fly ash may give similar removal efficiencies. The TOXECON process avoids the problem of carbon-containing fly ash being unsuitable for cement production.
- Coal cleaning, other additives and sorbents, catalytic- and plasma-based processes, and other advanced technologies are being developed and demonstrated for Hg and multipollutant removal but have not been well demonstrated in commercial operations. Cost claims for these alternatives vary, with some multipollutant technology developers asserting costs below conventional SO_2, PM, and NOx removal. Integrated gasification combined cycle (IGCC) can achieve high pollutant removal efficiencies and is claimed by some to be comparable in price to building a new supercritical pulverized coal plant.
- Regardless of technology employed, consideration should be given to the fate of Hg captured in scrubber sludge, by PM controls, or through other means to assure that Hg does not become an environmental threat through other routes. The Hg has to go somewhere.
- EPA has proposed Hg controls on EGUs, though many have criticized proposed emissions trading provisions and alleged weakness of the requirements. Several states are enacting mercury control requirements on EGUs while others--such as North Carolina--contemplate doing so soon.

Issue

Mercury is a neurotoxin that in certain forms can cause abnormal brain development in fetuses and mental retardation and learning disabilities in children. EPA estimates that one to three percent of American women of childbearing age eat enough mercury-containing fish to be at risk.[2] However other studies suggest that eight percent of such women may have mercury levels that could harm a fetus.[3] Fish tissue studies have prompted consumption advisories and restrictions for certain species caught in segments of Virginia's and other states' waterways.[4] Also, the Food and Drug Administration and EPA have issued advice on consumption of marine fish due to mercury. Past EPA actions have led to reductions in air and water releases of mercury from a number of industries. Pollution prevention approaches are helping reduce the presence of mercury in many products. Currently a number of states and the EPA propose to regulate mercury emissions from coal-fired power plants, which are the largest anthropogenic sources of mercury emissions.[5, 6]

Mercury Routes and Sources

In some waterways mercury contamination can be ascribed to surface releases from specific industrial plants and contaminated lands. In other cases smaller sources, such as dental practices, may, via municipal wastewater treatment plants, be major contributors of a watershed's Hg load. However, there are many waterways where air deposition appears to be the primary route of Hg contamination.

Relatively stagnant and acidic "blackwaters," such as in Southastern Virginia, Eastern North Carolina, and the Florida Everglades appear to be particularly vulnerable to the reactions that create methylmercury, an organic compound that bioaccumulates in fish, wildlife, and human beings.[7]

A national mercury deposition network (MDN) has measured wet (rain and snow) but not dry deposition of Hg.[8] There are no MDN sites in Virginia but two sites in Eastern North Carolina are illustrative. North Carolina notes a modest correlation between reducing nearby Hg emissions and reduced deposition. However, the state correlates its relatively high emissions with high ambient air Hg levels, high wet air deposition amounts, and high levels in selected fish species and the people who eat those fish.

Florida has seen a more dramatic correlation between local emissions and fish and wildlife Hg levels.[9] The state estimates that 98% of mercury contamination in the Everglades is from air deposition and that over half of that mercury is emitted locally. Florida DEP concludes that reductions in local air emissions of mercury resulted in a 60% decline in Everglades' fish and wildlife mercury levels over a 15-year period since peak mercury emissions. The emissions reductions were primarily accomplished through a shutdown of a waste incinerator and measures taken at other waste-to-energy plants to prevent combustion of mercury-containing wastes.

Nationally, EPA estimates coal-fired electric power plants to account for 40% of U.S. manmade mercury emissions.[10] Industrial boilers account for 10%, hazardous waste incinerators 5%, and chlorine production about 5%. Municipal and medical waste incinerators each account for fewer than 5%, down from much higher levels in the past before MACT standards were implemented. Other industrial processes, such as scrap steel recycling, can be locally and regionally significant Hg emission sources.[11]

Virginia Sources of Mercury Air Emissions[12]

The Toxic Release Inventory reports 1.09 tons of mercury compounds released to the air in Virginia in 2002, of which 0.643 tons came from electric utilities. The Environmental Working Group used EPA and Department of Energy data to estimate 0.688 tons emitted by nine Dominion Virginia Power, American Electric Power, and Potomac Electric Power Co. power stations in 1998. EPA's Electric Utility Mercury Software Tool estimates 0.63 tons of mercury emissions from 36 Virginia EGUs in 1999. While these estimates vary somewhat, they all suggest roughly two-thirds of a ton emitted annually by Virginia electric utilities.

Mercury Controls[13]

PM and SO_2 controls can achieve significant mercury reduction as a co-benefit. The following table adapted from presentations at a North Carolina Division of Air Quality workshop illustrates such reductions:

Controls	Bituminous (% removal)	Duke Energy expectations for conformance with the NC Clean Smokestacks Act (% removal from bituminous)	Subbituminous (% removal)
PM Only			
Cold side (CS)-ESP	46	25 to 35	16
Hot side (HS)-ESP	12	0 to 9	13
Fabric Filter (FF)	83		72
PM scrubber	14		0
Dry FGD			
SDA + ESP			38
SDA + FF	98		25
Wet FGD			
CS-ESP + Wet FGD	81	80 to 90 (with SCR) 55 to 65 (w/o SCR)	35
HS-ESP + Wet FGD	55		33
FF + Wet FGD	96		

ESP: electrostatic precipitator; FGD: flue-gas desulfurization; SDA: spray dryer adsorber; SCR: selective catalytic reduction of NOx.

The reader is cautioned that mercury removal by wet FGD varies considerably depending on coal quality and combustion and post-combustion conditions. This is because elemental mercury is poorly soluble in water whereas oxidized or reactive compounds of mercury as well as particulate-bound mercury are more easily scrubbed. SCR for NOx control helps convert elemental Hg to HgCl, which is more easily scrubbed by FGD, but at a possible cost of increasing corrosivity of flue gases. Some low-NOx burners leave some carbon in fly ash, which enhances mercury removal.

According to EPA's Electric Utility Mercury Software Tool, Virginia EGUs that employ both FGD (or fluidized bed combustion in one case) and fabric filter are estimated to achieve 92 to 99% Hg control.[14] EGUs with CS-ESP and no FGD get 29% and those with HS-ESP and no FGD just 11%.

Specific Hg abatement measures are also being developed. The most mature of these is injection of activated carbon into flue gas. Incomplete combustion of coal to leave some carbon in fly ash is another technique that employs the same Hg adsorption mechanism. Some consider activated carbon injection to be commercially available now since eight long-term full-scale tests have been performed with another dozen under way or close at hand. Carbon adsorbs Hg, including, apparently, the elemental form. Based on commercial scale tests, activated carbon injection combined with CS-ESP or fabric filter can yield over 70% Hg removal efficiency even in the absence of FGD.

To retrofit a 250 MW plant that has a CS-ESP and operates at 80% capacity factor with an activated carbon system designed for 70% Hg removal would cost $790,000 for the carbon injection system plus annual carbon costs of $2.56 million. If retrofitted with a fabric filter, capital costs would include $12.5 million for the fabric filter plus $790,000 for the injection system. However only $769,000 of carbon would be consumed annually. So there is a tradeoff between capital and operating costs in opting between ESP and fabric filter. It should be noted that these costs are a function of plant size, not the amount of Hg removed.

A disadvantage of activated carbon injection or leaving carbon in fly ash through combustion controls is that the resulting fly ash is unsuitable for cement production. The EPRI-developed TOXECON system solves this problem by incorporating two PM controls. An ESP collects over 90% of fly ash, which is then available for cement manufacture. Then carbon is injected into the remaining exhaust, followed by particulate and thus Hg removal by a fabric filter.

A number of other sorbents, additives, pre-combustion coal cleaning approaches, catalysts, electron beam, and low temperature plasma approaches are being developed and tested to control Hg specifically or as part of multipollutant controls. While some have been tested on a utility-scale and some are claimed to offer cost advantages over a conventional ensemble of PM control-FGD-SCR, none have been applied widely enough to be considered commercially proven.

For new coal-fired plants IGCC may be an option. IGCC can achieve very low emissions for all regulated pollutants. For Hg control, running a relatively small volume of synthesis gas over a carbon bed is easier than treating very large volumes of flue gas. This approach is used to remove mercury at a number of mercury-rich natural gas deposits. New gasification technologies operate at high temperatures to avoid hazardous organic wastes associated with earlier syngas and town gas production. Some claim that the cost of IGCC is similar to that of a new supercritical pulverized coal plant with pollution controls. Reportedly some states are considering finding IGCC to be best available control technology (BACT) for new utility coal-fired EGUs.

Whether collected as PM, scrubber sludge, or in other form the Hg has to go somewhere. Care should be taken to assure that air emissions controls do not simply transfer the Hg problem to another medium through another route. Decreased Hg use in commerce suggests limited opportunities to recover Hg for recycling. Life-cycle and industrial ecology approaches may be useful for understanding best Hg management options.[15]

Conclusions

Hg is increasingly viewed as a public health and environmental hazard requiring action. Data indicate coal-fired EGUs to be the largest anthropogenic source of Hg. Both short- and long-range transport and deposition may contribute to locally high levels of Hg in fish tissue. Data from Florida and North Carolina correlate reduced local Hg emissions to lower quantities deposited and found in fish and wildlife. However, the correlations vary in strength.

Conventional PM and SO_2 control technologies yield Hg control as a co-benefit. SCR may also assist in removal efficiencies. A combination of FGD (wet or SDA) plus fabric filter can remove over 80 and even high 90s percent of Hg when bituminous coal is burned. Fabric filtration alone may remove the majority of Hg from bituminous coal derived flue gas. CS-ESP alone may remove a quarter or more while HS-ESP removes little. Removal efficiencies are affected by coal quality and combustion and post-combustion conditions.

Activated carbon injection is the most mature Hg-focused pollution control technique and a system exists to counter the problem of carbon-rich fly ash being unsuitable for cement production. A variety of other technologies focused on Hg control or Hg control as part of a multipollutant control ensemble offer significant promise but are generally not considered to be commercially proven in the eyes of today’s electric utilities.

Hg management strategies should be mindful of the form, mobility, and fate of Hg recovered by pollution controls. It is important to avoid creating other Hg-related environmental and health risks as a by-product of coal combustion pollution control. The Hg has to go somewhere.

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[1] References are not indicated in the summary but are cited in abbreviated form in subsequent sections. Formal citations and references available on request.

[2] Cited in "POWERful Facts About Mercury in North Carolina," Center for Energy and Economic Development (undated, no other publication information, distributed at the NC Division of Air Quality, *Mercury and Carbon Dioxide Workshop*, Raleigh, NC, April 19-21, 2004.

[3] Cited in "Who'll Stop the Mercury Rain?" *U.S. News & World Report*, April 5, 2004.

[4] Virginia Hg-related fish consumption restrictions and advisories are in place for segments of the North Fork Holston River; South, South Fork Shenandoah, and Shenandoah Rivers; Blackwater River; Great Dismal Swamp Canal; and Dragon Run Swamp. The latter three are "blackwater" areas and their Hg contamination has not so far been associated with any obvious surface sources. Alex Barron (VA DEQ) and materials distributed at the Virginia DEQ water program Mercury Advisory Committee meeting held April 16, 2004.

[5] EPA has offered three proposed approaches including a MACT, a modified MACT with a tradable allowance component, and a cap-and-trade program under Clean Air Act Section 111 authority. These are still in the comment stage and have engendered controversy. William Maxwell (EPA) at the *Mercury and Carbon Dioxide Workshop*.

[6] CT has a rule and WI, MA, and NJ are developing rules regulating EGU Hg emissions. NH and NC will develop recommendations to the legislature for Hg controls in 2004 and 2005, respectively, under the NH Clean Power Act and NC Clean Smokestacks Act. Several other states, including VA (Del. Reid's bill), have proposed bills or assembled task forces to examine and address Hg emissions. Martha Keating (Clean Air Task Force) at the *Mercury and Carbon Dioxide Workshop*.

[7] Conclusions from Virginia DEQ water program Mercury Advisory Committee meeting held April 16, 2004 and presentations by Michelle Woolfork (NC Division of Water Quality) and by Thomas Atkeson (FL DEP), Robert Steven (FL DEP), and Matthew Landis (U.S. EPA) at the *Mercury and Carbon Dioxide Workshop*.

[8] Steve Schliesser and Todd Crawford (NC Division of Air Quality) at the *Mercury and Carbon Dioxide Workshop.*

[9] Thomas Atkeson (FL DEP), Robert Steven (FL DEP), and Matthew Landis (U.S. EPA) at the *Mercury and Carbon Dioxide Workshop.*

[10] U.S. EPA “Frequent Questions” fact sheet on mercury at http://www.epa.gov/mercury/information1.html

[11] For example, the Virginia Toxic Release Inventory (TRI) for 2002 shows a Chaparral Steel facility as having emitted 0.145 tons of Hg, which is 13.3% of Hg air emissions from all TRI reporting manufacturing and utility facilities in Virginia. This amount is much greater than that emitted annually by any single electrical generating unity in Virginia and greater than all but one electrical generating station (four units constituting the Chesterfield Power Station).

[12] DEQ TRI report for 2002; Environmental Working Group at http://www.ewg.org/reports_content/mercuryfalling/Virginia.pdf ; EPA's Electric Utility Mercury Software Tool available for download at http://www.epa.gov/ttn/atw/combust/utiltox/utoxpg.html

[13] This section is based largely on Michael Durham (ADA Environmental Solutions) “Performance and Costs of Mercury Controls for Bituminous Coals” at the *Mercury and Carbon Dioxide Workshop* except Duke Energy Hg control expectations are from Robert McMurry (Duke Power) and information on IGCC is from Joe Chaisson (Clean Air Task Force), both at the *Mercury and Carbon Dioxide Workshop*. Also Virginia EGU information is from EPA's Electric Utility Mercury Software Tool, previously cited.

[14] AES Warrior Run, Clover Power Station, LG&E-Westmoreland, Mecklenburg Cogeneration, and SEI-Birchwood achieve over 90% Hg removal.

[15] The case of scrap steel recycling, including the Chaparral Steel facility previously cited, is illustrative. In that industry Hg emissions are due to Hg contained in scrap, such as Hg-containing switches in scrapped automobiles. The solution to this problem is for automobile manufacturers to avoid using Hg-containing components. A number of foreign automobile makers have phased out Hg-containing switches while U.S. manufacturers have been slower to do so. While this solution is not applicable to Hg from EGUs, the point is the need to look broadly at the source, form, and fate of pollutants and to consider options beyond end-of-pipe pollution controls.

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